LV. *A Discourse on the Parallax of the* Sun. *By the Rev.* Thomas Hornsby, *M. A.* Savilian *Professor of Astronomy in the University of* Oxford, *and F. R. S.*

Read Dec. 23, 1763.

THE quantity of the Sun's parallax is of such importance both to the theory and practical part of astronomy, that every method of determining it hath been employed by the astronomers of every age. Mr. Flamsteed informs us, in the 92d and 96th numbers of the Philosophical Transactions, that from some observations made upon the planet Mars, he had found the Sun's parallax not to exceed 10 seconds; and Dr. Halley, in a memoir written expressly with a view to ascertain the exact quantity of it, supposes it not to be greater than 12″ $\frac{1}{2}$.

When we consider the imperfect state of astronomy at the time when Mr. Horrox lived, we cannot sufficiently admire the wonderful genius of that young gentleman, who at the age of 24 could collect from his own observations, that the parallax of the Sun did not exceed 14 seconds; while many celebrated astronomers, whose tables were then in the greatest repute, had assigned a parallax of more than two minutes to the Sun, which Kepler had supposed could not be less than 59 seconds, and which Hevelius, who published the admirable treatise of Mr. Horrox, intitled, Venus in Sole visa, fixed at 41 seconds.

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In the year 1719, Dr. Pound and his nephew, that illuſtrious aſtronomer, Mr. Bradley, did, when Mars was in oppoſition to the Sun, demonſtrate (to uſe the words of Dr. Halley, Phil. Tranſ. N°. 366, p. 114.) the extreme minuteneſs of the Sun's parallax, and that it was not more than 12″, nor leſs than 9″, upon many repeated trials. At the ſame time and by the ſame kind of obſervations Mr. Maraldi determined this parallax to be 10″, the reſult of his obſervations agreeing exactly with thoſe deduced from the correſpondent obſervations by Mr. Richer at Cayenne and by Mr. Caſſini at Paris in the year 1672.

The voyage which the Abbè de la Caille undertook, to perfect a catalogue of ſome of the principal fixt ſtars, furniſhed the aſtronomers with the means of determining the Sun's parallax by correſponding altitudes of the planets Mars and Venus, to be obſerved on each ſide of the equator, with all the accuracy of which that method is capable The aſtronomers here in Europe were invited to determine the diſtances of the planets from particular ſtars on ſtated days, while the Abbè himſelf propoſed to make the correſponding obſervations on the ſouthernmoſt part of Africa at the Cape of Good Hope. By the differences of the altitudes of the northern limb of Mars and of ſuch ſtars as were nearly in the ſame parallel obſerved on the ſame day at the Cape with a ſextant of 6 f. radius; at Greenwich by Dr. Bradley with a mural quadrant of 8 f.; at Bologna in Italy by M. Zanotti with a ſimilar inſtrument of 5f.; at the Royal Obſervatory at Paris by Meſſieurs Caſſini de Thury and Gentil with a moveable quadrant of 6 f.; and in Sweden by Meſſieurs Wargentin, Stronmer and Schem-

Schemmark, with teleſcopes of 7 and 8 f. armed with micrometers, it was found, when every reduction is made, that, according to each obſervation, the dates of which are given below, the horizontal parallax of the Sun, when at its mean diſtance from the earth, was as is repreſented in the following table.

Greenwich.		Bologna.		Paris.		Stockholm.		Upſal.		Hernoſand.	
1751.	″	1751.	″	1751.	″	1751.	″	1751.	″	1751.	″
Aug. - - 30	9, 677	Aug. 31	9, 753	Sept. 13	9, 134	Sept. 1	10, 466	Sept. 2	9, 438	Sept. 25	9, 933
Sept. - - 13	9, 324	Sept. 1	9, 895	14	9, 715	25	10, 504	+ 24	12, 255	27	10, 618
14	9, 096	13	9, 971	+ 24	11, 912	Oct. + 3	12, 864	25	9, 715		
Oct. - - 3	10, 161	14	10, 238	Oct. 8	9, 895	5	10, 085	Oct. 6	9, 134		
4	10, 504	Oct. + 7	11, 075			6	9, 735				
7	9, 515										
+ 9	10, 961										
Mean of all	9, 891		10, 186		10, 164		10, 734		10, 135		10, 275
Mean rej. +	9, 712		9, 964		9, 581		10, 202		9, 421		

By taking a mean of all the obſervations, it follows that the Sun's mean horizontal parallax is 10″, 2; and if we reject the obſervations which differ moſt in exceſs from the reſt, the mean will give 9,842 for the Sun's mean horizontal parallax.

Beſides theſe 27 determinations, the Abbè de la Caille compared 41 obſervations, the mean of which is given in the following table.

N° of Obſ.	Obſervations.	Inſtruments.	Places.	☉ Par.
				″
7	The late M. Caſſini and M. Maraldi	Quadrant 2 f. rad.	Thury	8, 982
6	Mr. Deliſle — at the Hotel de Clugny	Mur. circle 2 f.	Paris †	11 532
3	Father Beraud	Refr. tel. 7 f.	Lyons	9, 020
6	M. M. Garipuy and d'Arquier	Ditto.	Toulouſe	8, 944
12	M. Sabatelli and Father Carcani	Quad. 4f. diag. div.	Naples	9, 933
7	M. Boſe	Tel. of 6 and 8 f.	Wittemberg	10 999
	Mean of all obſerv. according to A. Caille			10, 210
	Mean of Reſults (rejecting the 2d)			9, 575

 Few

Few obſervations of Venus near the inferior conjunction with the Sun on Oct. 31. 1751 were made, on account of the unfavourable weather here in Europe. By an obſervation made at Greenwich on Oct. 25, the mean horizontal parallax was 9″,8; but according to the obſervation made at Paris on the ſame day at the Royal Obſervatory, that parallax was 11″,4. On Oct. 27, by an obſervation made at Paris, the ☉'s mean horizontal parallax was 9″,85; but by an obſervation at Bologna on the ſame day it was found to be 10″,4 —— By the obſervation at Paris on Nov. 17, the Sun's mean parallax was 10″,5. By a mean of all the obſervations of Venus, the Sun's mean parallax is 10″,38; and if we reject the Paris obſervation on Oct. 25, that parallax is 10″,13*.

We ſee then that, according to theſe obſervations, the Sun's mean horizontal parallax is not leſs than 8″, 94. If we take a mean of the whole, that quantity is 10,09: But if we reject the obſervations that differ moſt in exceſs, the Sun's mean horizontal parallax will be found to be 9″,92 a determination in which every aſtronomer might readily acquieſce, when he conſiders the accuracy of the obſervers and the nice agreement of almoſt all the obſervations.

And ſuch was the ſtate of the Sun's parallax as deduced from the lateſt and beſt obſervations, when the approaching tranſit of Venus in 1761 engaged the attention of the curious of all nations. Dr. Halley, in Philoſophical Tranſactions, N°. 348, had propoſed a method of determining the Sun's parallax

* See the Abbè de la Caille's Introduction to his Ephemerides Celeſtes from 1765 to 1774.

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by procuring obſervations to be made upon this tranſit in ſuch places where the difference of time between the ingreſs and egreſs would be the greateſt poſſible; namely near the mouth of the Ganges, where the Sun would be vertical at the middle of the tranſit, and at Port-Nelſon in Hudſon's-Bay, where the planet would enter upon the Sun's diſk about the time of Sun-ſet, and leave it ſoon after Sun-riſing; for in the former place, ſays Dr. Halley, the planet would be equally diſtant from noon both at ingreſs and egreſs, and the apparent motion of Venus upon the Sun would be accelerated by almoſt double the quantity of the horizontal parallax of Venus from the Sun: becauſe Venus is at that time retrograde, and moves in a direction contrary to that of the eye of an obſerver upon the earth's ſurface. Whereas in Hudſon's-Bay, under an oppoſite meridian, the eye of an obſerver will be carried, while the Sun ſeems to move under the pole from ſetting to riſing, in a direction contrary to the motion of the obſerver's eye at the Ganges; that is, in the direction of the planet's retrograde motion from eaſt to weſt.—From theſe conſiderations, and ſuppoſing with Dr. Halley the axis of the planet's path to be inclined to the axis of the equator in an angle of 2°.18′ only, the interval between the two contacts would have been 15′. 10″ longer in Hudſon's Bay than at the mouth of the Ganges.

But upon examination the caſe is found to be ſomewhat different. The axis of the equator on the 6th of June 1761 made an angle of 6° 10′ with the axis of the ecliptic on one ſide, and the axis of the planet's path an angle of 8°.30′.10″ on the other; the axis of the planet's path therefore made an angle with the equator of 14°. 40′. 10″.—The planet's latitude was 5 ½ minutes greater both from obſervation and

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the Doctor's own tables, than he had ſuppoſed in his calculation made from the Rodolphine tables corrected: and therefore the planet's egreſs could not have been obſerved at Port Nelſon. Having made a computation for a place in North America ſituated $5^h. 30'$ to the weſt of Greenwich, and in the 60th degree of latitude; and alſo for a place to the eaſt of Ganges, and $6^h. 30'$ to the eaſt of Greenwich in the latitude of $22°. 42'$ north, that the places might be nearly ſituated in the ſame circumſtances with the mouth of the Ganges and Port Nelſon, I find that the interval between the two contacts would be but $4'. 56''$ longer in America than in the Eaſt Indies, ſuppoſing the Sun's parallax $12''.5$, and the inclination of Venus's path $14°. 40'$ to the equator.

And here perhaps it may not be altogether unneceſſary to enquire how far the miſtake which Dr. Halley committed, by uſing the difference of the two angles inſtead of their ſum, would influence the times of the tranſit as ſeen at Ganges and Port Nelſon. For this purpoſe I made uſe of the ſame elements which Dr. Halley has given in his paper, and calculated the angle of the vertical with the orbit of Venus at the two internal contacts at both places, ſuppoſing the orbit to be inclined firſt only $2°. 18'$ to the equator, agreably to Dr. Halley's ſuppoſition, and alſo $14°. 40'$. and I found that the duration would be $15'. 13''$ longer at Hudſon's-Bay than at the Ganges upon the firſt ſuppoſition; and $14'. 44''$, if the circles be duly inclined to each other; the difference being only 29 ſeconds. It has already been found by calculation, ſuppoſing the latitude of Venus to be about $9\frac{1}{2}$ minutes, that the difference of duration at the two places would have been only $4'. 56''$. It may

fairly

fairly therefore be concluded that the tranſpoſition of the circles contributed very little towards giving ſo different a reſult, the reaſon of which need not here be mentioned; and Dr. Halley ſeems to have been led into the miſtake entirely from ſuppoſing the latitude of Venus to be about $4'.0''$ according to the tables, which he then uſed, conſtructed upon the principle that the nodes of that planet were fixed.—Having determined that the difference of duration at the two places above mentioned would be $15'.10''$ (differing only $3''$ from the method I uſed which is independent of projection) the Doctor proceeds to ſhew, that if Venus had no latitude at the time of the middle of the tranſit, the difference would be $18'.40''$; and if the planet ſhould paſs $4'.0''$ to the north of the Sun's center, that difference would be $21'.40''$, and would become ſtill greater, if the planet's north latitude ſhould be farther increaſed. And ſuch would have been the event, had the motion of the nodes been progreſſive. But, agreably to the principles of univerſal attraction, their motion is really retrograde, and this Dr. Halley ſays he himſelf ſuſpected, *ut ob nuperas quaſdam obſervationes ſuſpicio eſt*. And therefore it is ſomewhat ſurpriſing that he did not determine by calculation what would have been the difference in the whole duration between the two places, if Venus ſhould paſs more to the ſouthward of the Sun's center, then he had ſuppoſed. He would then immediately have perceived that the two ſtations were not ſo advantageouſly placed, as the ſolution of the problem required.

Obſervers were therefore to be ſent to other places, in order to determine the Sun's parallax agreeably to the method propoſed by Dr. Halley. The city of Tobolſki

Tobolſki in Siberia is ſo ſituated, that the interval between the two contacts was perhaps as ſhort as could poſſibly be obſerved on any part of the earth's ſurface; to this place was ſent the Abbè Chappe d'Auteroches, one of the French aſtronomers. Near Hudſon's Bay and in 60° of latitude the duration would have been 5 minutes longer, ſuppoſing the Sun's parallax $=9''$. At Bencoolen, where it was firſt propoſed to ſend Meſs. Maſon and Dixon, the difference would have been about $4\frac{1}{2}$ minutes. At the iſland of Rodrigues, where Mr. Pingré could only obſerve the laſt internal contact, the difference would have been about $7\frac{1}{2}$ minutes. On the ſouthern coaſt of New-Holland, it would have been ſomewhat more than 10 minutes. And in the great Indian Ocean, under $115\frac{1}{4}$ of abſolute longitude from the Iſle of Ferro and in 57° of ſouth latitude, where the begining of the tranſit would happen ſoon after Sun-riſing, and the end juſt before Sun-ſet, the difference would amount to $13\frac{1}{4}$ minutes. The greateſt difference between the interval of the two internal contacts, as determined by actual obſervation on the 6th of June, was $2'.49'',75$, a quantity hardly ſufficient to determine the Sun's parallax agreeably to the method propoſed by Dr. Halley.

I have however made the neceſſary calculations, and compared the duration of the tranſit obſerved at ſeveral places with the duration as obſerved at Tobolſki. The parallax reſulting from each obſervation is contained in the following table, in which the 3d column contains the obſerved duration, the 4th the difference of each obſerved duration; the next contains that difference as deduced by computation upon a ſuppoſition that the Sun's parallax is $9''$. In the laſt

last column is given the horizontal parallax on the day of the transit, resulting from a comparison of the 4th and 5th columns.

Places.	Observers.	Observed duration.	Difference of observ'd dur.	Difference by calculation.	Sun's Parallax.
		h ′ ″	″	′ ″	″
Tobolski	Abbe Chappe	5 48 53,25			
Cajaneburg	Mr. Planmann	5 49 54	1 00,75	1 00,88	8,980
Tornea°	Hellant	5 50 09	1 15,75	1 05,27	10,444
Tornea°	Lagerborn	5 50 21	1 27,75	1 05,27	†12,098
Upsal	Bergman	5 50 26	1 32,75	1 33,78	8,901
Upsal	Mallet	5 50 07	1 13,75	1 33,78	† 7,077
Upsal	Strömer	5 50 02	1 08,75	1 33,78	† 6,597
Hernosand	Gister	5 50 26	1 32,75	1 25,76	9,733
Abo	Justander	5 50 09	1 15,75	1 20,68	8,450
Stockholm	Wargentin	5 50 45	1 51,75	1 34,21	10,675
Stockholm	Klingenstiern	5 50 42	1 48,75	1 34,21	10,389
Calcutta	Magee	5 50 31	1 37,75	1 37,02	9,067
Madrass	Hirst	5 51 43	2 49,75	2 39,50	9,577
Mean of the whole - - - - - - - - - -					9,332
Mean, rejecting 2 observations at Upsal and 1 at Tornea					9,579

The duration at Cajaneburg was the shortest except at Tobolski; with which if we compare the duration observed at Madrass the parallax is 9″,948: and by taking a mean of the parallax deduced from a comparison of the observation at Madrass with those of Tobolski and Cajaneburg, the parallax is 9″,762.

The observations at the above places agree as well together as can be expected from such small differences in the duration, which must in some measure be influenced by the necessary and unavoidable errors in observation.

If

If the quantity of the ſun's diameter, and the leaſt diſtance of the centers were very exactly known, tha Sun's parallax might ſafely be determined by comparing the duration of the tranſit as obſerved at different places w'th the duration as ſuppoſed to be ſeen from the ear h's center. According to this method, ſuppoſing tl e leaſt diſtance of the centers to be $9'.29''\frac{1}{2}$, which is a mean between the Greenwich Shirburn and Pari obſervations, and the difference of the ſemidiameters of the Sun and Venus$=916'',4$, the duration as ol ſerved at Tobolſki was more than 10 minutes ſhorte than if ſeen without parallax; at Tornea°, at Stock iolm, at Cajaneburg, at Aſtracan, and indeed in alm ſt every part of Europe and Aſia, the duration was conſiderably ſhortened; and if a number of good obſervations made in ſeveral of thoſe parts were procured, the Quantity of the Sun's, parallax might be well enough aſcertained, as the difference in duration for a difference of one ſecond in the Sun's parallax will be found very conſiderable.

Tho' this method ſhould not be practiſed, unleſs the neceſſary requiſites for the computation be known with ſome degree of preciſion, I have ventured to compare the durations obſerved chiefly in the northern parts of Europe, and ſome in Aſia, with the duration, as ſeen from the earth's center,$=5^h.59'.19'',10$ mean time, or $5^h.59'.16'',64$ apparent time, and calculated from the elements above mentioned.

Places

Places.	Obferved durations.	Duration without parallax.	Difference of durations.	Differ. for 1'' of parallax.	Sun's parallax.
	h ′ ″	h ′ ″	′ ″	″	″
Tobolfki - -	5 48 53 25	5 59 16, 64	10 23, 39	64, 09	9, 726
Cajaneburg -	5 49 54		9 22, 64	57, 32	9, 815
Tornea° - -	5 50 09		9 17, 64	56, 83	9, 636
Tornea° - -	5 50 21		8 55, 64	56, 83	9, 425
Abo - - - -	5 50 09		9 07, 64	55, 12	9, 935
Upfal - - -	5 50 26		8 50, 64	53, 67	9, 888
Upfal - - -	5 50 07		9 09, 64	53, 67	10, 241
Upfal - - -	5 50 02		9 15, 64	53, 67	10, 352
Hernofand -	5 50 26		8 50, 64	53, 65	9, 890
Stockholm -	5 50 42		8 34, 64	53, 62	9, 579
Stockholm -	5 50 45		8 31, 64	53, 62	9, 523
Calcutta - -	5 50 36		8 40, 64	53, 31	9, 766
Madrafs - -	5 51 43		7 33, 64	46, 36	9, 785

N. B. The 4th column contains the difference between the obferved and calculated duration; in the 5th is given the difference in the duration for a difference of 1″ in the ☉'s parallax, and the 6th column is obtained by dividing the 4th by the 5th.

The mean of all the refults is 9″,812: and if we reject two of the obfervations at Upfal, which differ moft in excefs, the Sun's parallax is 9″,724, agreeing very nearly with the quantity refulting from a comparifon of fome of the obferved durations with the fhorteft obferved at Tobolfki and Cajaneburg.

We may alfo proceed to find the Sun's parallax by means of the leaft diftance of the centers as obferved in two or more places where the effect of parallax was contrary; or if the leaft diftance of the centers was only determined at one place, it may be found by calculation at any other place, where the total duration was obferved. But in this and the laft cafe the elements of calculation are required with fo rigorous

exactness, that perhaps these methods are only to be called in to illustrate and confirm the others.

Mr. Pingré confined himself principally to the determination of the least distance of the centers. At $21^h.43'.11''$ he found the distance between the nearest limbs of Venus and the Sun to be the greatest $= 5'.57'',2$. or $5'.57'',4$ when corrected by refraction. This distance being subtracted from $15'.19'',5$ the difference of the Semidiameters, leaves $9'.22'',1$ for the least apparent distance of the centers. But as that observation was made rather too late, when the distance of the centers was greater than it ought to be, he found by calculation that it should be diminished by $0'',22$. The true apparent least distance of the centers by actual observation was therefore $9'.21'',88$. In order to be more secure of this result, Mr. Pingré compared a large number of observed distances, both at the beginning and towards the middle of the transit, with the distance determined by internal contact, and after excluding every doubtful observation, he found the least apparent distance of the centers to be $9'.21'',69$. By comparing this distance with the distance deduced from the total duration as observed at any place (the method of finding which he has given at large in his memoir inserted in the Memoirs of the academy of sciences for 1761) and by knowing from calculation what influence a parallax of $10''$ for instance would have upon those distances, he found the Sun's parallax as in the following table.

Places

Places.	Observed durations.	L. diſtance of centers from the durations.	L. diſtance deduced from calculation.	Sun's parallax.
	h ′ ″	′ ″	′ ″	″
Tobolſki - - - - - -	5 48 53,25	9 51,53	9 52,24	10,125
Stockholm - - -	5 50 43,5	9 54,85	9 55,83	10,03
Upſal - - - - - - - -	5 50 26	9 55,62	9 55,95	10,23
Cajaneburg - - - -	5 49 54	9 55,61	9 55,61	10,00
Tornea° - - - - - -	5 50 09	9 55,28	9 56,08	10,09

By taking a mean of theſe determinations, we find the Sun's parallax to be 10″,1. In the above calculations the Sun's ſemi-diameter was ſuppoſed = 15′.48″,5, and that of Venus 29″. Obſervers, ſays Mr. Pingré, have found the former to be about 2″ leſs, and the latter on the contrary half a ſecond larger. By calculating upon the ſuppoſition of a difference of 2″ in the difference of the ſemidiameters of the Sun and Venus, the leaſt diſtance of the centers at Tobolſki, Stockholm, Upſal, Tornea°, and Cajaneburg, ought to be 3″, 12 leſs, and at Rodrigues 2″,56 or 2″,60, and the Sun's horizontal parallax ought alſo to be 0″,17 leſs. If then this correction be admitted, which is warranted by the beſt obſervations, the Sun's horizontal parallax will be 9″,92.

There is ſtill another method by which we are enabled to determine the Sun's parallax, by comparing the obſervations made in different places where the effect of parallax upon the planet is conſiderable at the times of the two contacts. It was more convenient to make uſe of the 2d internal contact for this purpoſe, and the obſervers were very advantageouſly ſtationed at St. Helena and the Cape of Good

 Hope:

Hope: for by comparing the obſervations made there with thoſe at Tornea°, Toboljki, and in ſome of the Eaſtern parts of Aſia, the difference of the times of the contacts when reduced to the ſame meridian will be found to be very conſiderable, amounting to more than 9 $\frac{1}{2}$ minutes at the two firſt places above mentioned, and being greater, as the places are farther ſituated to the North-Eaſt. But if this method be uſed, it is abſolutely neceſſary that the longitudes of the places ſhould be determined with the utmoſt accuracy, ſince an error of a few ſeconds would have a conſiderable influence upon the reſult, and would increaſe or diminiſh the quantity of the Sun's parallax, in proportion. The unfavourable ſtate of the heavens at the time of the internal contact prevented the Rev. Mr. *Maſkelyne* from making an obſervation at the Iſle of St. Helena; which is the more to be lamented as his obſervation would have confirmed or corrected the obſervation at the Cape, if neceſſary; ſince the effect of parallax at both places would have been very nearly the ſame. The obſervers at the Cape were more fortunate, and differed only 4″ in their obſervation of the internal contact. — But before we proceed to deduce the quantity of the Sun's parallax, by comparing as well the obſervation made at Greenwich as thoſe at other places, with the obſervation at the Cape, it will be neceſſary to lay before the reader the authorities upon which the longitude of each place has been determined.

The longitude of the Cape of Good-Hope was not even nearly known till the Abbé de la Caille went thither in the year 1751. By a compariſon of 9 eclipſes of Jupiter's ſatellites as well immerſions as emerſions obſerved at the Cape with the correſponding

ing obſervations made at Paris, the Cape was found by the Abbé de la Caille himſelf to be $1^h.4'.14''$ to the Eaſt of Paris, or $1^h.13'.31''$ to the Eaſt of Greenwich. Meſſ. Maſon and Dixon obſerved many eclipſes of Jupiter's ſatellites at the Cape, but the weather was not ſo favourable here in England. However by comparing four obſervations made in Surry-Street and one at Greenwich with thoſe made at the Cape, the difference of longitude at a mean is found to be $1^h.13'.28'$, which I have uſed in the following computations.

The internal contact, as reduced from ſiderial to apparent time by Mr. Maſon, happened at $21^h.39'.52''$.— But upon examination it will be found to have happened later: for whether we make uſe of the Sun's mean R. aſcenſion from the beſt ſolar tables extant, or the Sun's apparent R. aſcenſion reduced to the meridian of the place as determined by actual obſervation on the day of the tranſit, the true apparent time of the contact will be found to have happened at $21^h 39'.54$ — or at $21^h\ 39'.54''\frac{1}{2}$ if the time by the ſtar Antares be uſed, whoſe ſituation was more favourable to an obſerver in 34°. of South latitude. I ſhall therefore ſuppoſe the internal contact to have happened at $21^h.39'.52''$ by taking a mean of the two obſervations *.

The Royal Obſervatory at Paris was ſuppoſed by Sir Iſaac Newton, in his Principia, to be $9'.20''$ to the Eaſt of Greenwich. And the editor of Dr. Halley's

* Mr. Maſon, before he left England, acknowledged, in a letter to me, that he had committed a miſtake in his calculation, by forgetting to apply to the Sun's place the equation of præceſſion, which on the day of the tranſit amounted to —— $15'',6$.

ley's tables has followed that determination, which has alſo been generally uſed by the Engliſh Aſtronomers. — The French Aſtronomers have till very lately imagined the difference of meridians to be 9′.10″. as deduced from a ſingle obſervation of an eclipſe of Jupiter's firſt ſatellite made by Mr. Caſſini when in London, with a teleſcope of ſimilar ſize and conſtruction with that uſed at Paris when the ſame eclipſe was obſerved. — In the year 1734 Mr. Maraldi publiſhed a compariſon of 33 eclipſes obſerved at Greenwich by Mr. Flamſteed, and at Paris by the French Aſtronomers, 19 of which are immerſions, and the reſt emerſions. The longitudes reſulting from each correſpondent obſervation differ widely from each other, the two obſervatories being 11′.27″ diſtant by an immerſion of the 2d ſatellite, and only 7′ 43″ by an emerſion of the firſt. But if we take a mean of the whole, the difference of longitude will be 9′.24″; and if we exclude the obſervation of the 2d ſatellite above mentioned, which muſt be very faulty, the difference of meridians will be 9′.22″, a reſult which in all probability is but a very few ſeconds from the truth. It may be obſerved that the immerſions all give the difference of longitude too great, and almoſt all the emerſions too little; a circumſtance owing either to the badneſs of the air here in England, or to an inequality in the goodneſs of the teleſcopes, or perhaps to both; for whatever was the advantage in obſerving the immerſions, was ballanced by the emerſions: for which reaſon whenever the eclipſes of Jupiter's ſatellites are uſed, the longitude ſhould, if poſſible, be deduced both from immerſions and emerſions.

As the obſervations of tranſits of Mercury may be very uſeful in ſettling the longitudes of places which are

are not far diſtant, I have examined the ſeveral obſervations that I can meet with made at Paris, and either immediately at Greenwich or in ſuch parts of London whoſe longitude from Greenwich is known within one ſecond of time. And the reſult of ſuch compariſons is as follows.

On the 29th of October 1723 Dr. Halley obſerved the firſt interior contact of the limbs of Mercury and the Sun at $2^h.42'.26''$ apparent time at Greenwich. The Rev. Mr. Profeſſor Bradley obſerved the ſame at $2^h.42'.38''$, at Wanſted in Eſſex ($10''$ to the Eaſt of Greenwich) or at $2^h.42'.28''$ when reduced to the meridian of Greenwich. Mr. Graham in Fleetſtreet obſerved the ſame at $2^h.42'.19''$, or at $2^h.42'.44''$, when reduced to Greenwich. The mean of theſe is $2^h.42'.32'',7$. In the obſervatory at Paris Mr. Maraldi obſerved the ſame at $2^h.51'.48''$ apparent time; and Mr. Deliſle at $2^h.51'.37''$, but ſuſpects it might have been ſome few ſeconds later. I will ſuppoſe it to have happened at $2^h.51'.43'',5$. The difference of meridians therefore is $9'.10'',8$. If we take a mean of Dr. Halley's and Mr. Bradley's obſervations only, the difference of meridians is $9'.16'',5$.

In the year 1736 Dr. Bevis obſerved the laſt contacts of the limbs of Mercury and the Sun at $0^h\ 8'.33''$ at Greenwich. The ſame was obſerved at Paris by M. Maraldi and M. Caſſini de Thury, and at Thury by Mr. Caſſini, at $0^h.18'\ 05'',5$ by a mean of the three obſervations. The difference of longitude theretore is $9'.32'',5$.

In the year 1743 the laſt internal contact of the limbs was obſerved by Mr. Graham in Fleetſtreet at $1^h.0'.42''$, and by Dr. Bevis at Beaufort-Buildings in the

the Strand at $1^h.0'.33''$: or by a mean of both when reduced to the meridian of Greenwich at $1^h.1'.04''$.—The ſame was obſerved by the Abbé de la Caille, by Meſſ. Maraldi, Monnier, and Caſſini the ſon, at Paris, and by Mr. Caſſini at Thury: which obſervations, when reduced to the meridian of the Royal Obſervatory, give $1^h.10''.15'',5$ for the time of the internal contact: the difference of meridians is therefore $9'.12''.5$.——By a mean of the obſervations of Mr. Graham and Dr. Bevis when reduced to Greenwich, the laſt external contact on the ſame day happened at $1^h.2'.42''$. and by a mean of the obſervations in France the ſame happened there at $1^h.12'.10''$. The difference of longitude therefore is $9'.28''$. N B. No obſervations were made of this tranſit at the Royal Obſervatory at Greenwich, on account of clouds.

In the year 1753 was another tranſit of Mercury, when the unfavourable ſtate of the heavens a few ſeconds before the time of the internal contact prevented any obſervations from being made at Greenwich, as appears from a paper communicated to me by the executors of the late Dr. Bradley. Both contacts however were luckily very well obſerved, by Mr. Short, Dr. Bevis and Mr. Bird; by a mean of whoſe obſervations reduced to the meridian of Greenwich the internal contact happened at $10^h.9'.37'',5$. The ſame contact was obſerved by 13 obſervers at Paris, and was found not to happen ſooner than $10^h.18'.36''$, nor later than $10^h.19'.03''$. But by a mean of all at $10^h.18'.45''$. The difference of meridians therefore is $9'.07'',5$. By a mean of the obſervations of Mr. Short, Dr. Bevis, Mr. Bird, Mr. Canton, and Mr. Siſſon, all reduced to the meridian of Greenwich, the external

contact

contact happened at $10^h.12'.17'',5$. and at the Royal Observatory, by a mean of all the observations at Paris, at $10^h.21'.33''$. The difference of longitude therefore is $9'.15'',5$. And if we take a mean of these 7 results, the Royal Observatory at Paris will be found to be $9'.17''\frac{1}{2}$ to the East of the Royal Observatory at Greenwich, a determination very nearly agreeing with that mentioned by Sir Isaac Newton, and which, I believe, was deduced from a comparison of Dr. Halley's and Mr. Cassini's observations.

The Abbé de la Caille, in his memoire on the parallax of the Moon, supposes the difference of meridians to be $9'.17''$ tho' he has not mentioned from what authority he drew that conclusion. I shall therefore suppose the difference of meridians to be $9'.17''$.—The *last internal contact* was observed at Paris by Mr. de la Lande at $20^h.28'\,25''$ or $26''$; at $20^h.28'.26''$ by Father Clouet, and by Mr. Maraldi and Mr. Barros separately at $20^h.28'.42''$. Mr. Pingré, in a very curious memoire on the Sun's parallax already referred to, supposes the internal contact to have happened at Paris at $20^h.28'.38''$. I shall therefore make use of the Abbé de la Caille's observation at $20^h.\,28'.\,37''\,\frac{1}{2}$.

The difference of meridians between Paris and Stockholm, says Mr. Wargentin, is $1^h.2'.51''$ or $52''$ at most. Mr. de la Lande from a comparison of 17 observations of the first satellite of Jupiter made from 1750 to 1759 and communicated to him by Mr. Wargentin, determines the difference of longitude to be $1^h.3'.10''$. And the Abbé de la Caille, in his memoire on the Moon's parallax, supposes it to be $1^h.3'.13''$. As these two last determinations agree so nearly together, I shall suppose Stockholm to be

$1^h.3'.10''$ to the Eaſt of Paris, and $1^h.12'.27''$ to the Eaſt of Greenwich; and the laſt internal contact to have happened at $21^h.30'.09'',5$, which is a mean between the obſervations of Meſſ. Wargentin and Klingenſtiern.

The City of Cajaneburg in Sweden is $38'.40''$ to the Eaſt of Stockholm, according to very late obſervations; and therefore Cajaneburg is $1^h.51'.07''$ to the Eaſt of Greenwich. The 2d internal contact happened at $22^h.7'.59''$, when the error in writing down the minutes is corrected according to the inſtruction given in Philoſophical Tranſactions, for 1761, p. 231. Indeed (ſuppoſing the longitude of Cajaneburg as above ſet down to be exact) it is very eaſy to prove that the error of one minute was made at the egreſs rather than at the ingreſs.

The City of Tobolſki in Siberia (according to the obſervation of the end of the ſolar eclipſe on June 3d by Mr. Chappe and Mr. Planmann at Cajaneburg and calculated by Mr. Pingré) is $2^h.42'.11''$ to the Eaſt of Cajaneburg; and this determination is alſo confirmed by Mr. Wargentin's obſervation of the ſame phaſe. Tobolſki therefore is $4^h.33'.18''$ to the Eaſt of Greenwich: and I ſuppoſe Mr. Chappe to have obſerved the laſt internal contact at $0^h.49'.23''\frac{1}{2}$, without making any allowance for the luminous ring which appeared round Venus in his teleſcope.

The Obſervatory at Upſal (according to Mr. Wargentin in the Philoſophical Tranſactions) is $1^h.1'.10''$ to the Eaſt of Paris, and is therefore $1^h.10'.27''$ to the Eaſt of Greenwich. By taking a mean of the three obſervations made there, the internal contact happened at $21^h.28'.06''$.

Tornea°

Tornea° has been generally ſuppoſed to be $1^h.27'30''$ to the Eaſt of Paris; but with this difference of meridians, the obſervations at Tornea°, tho' made by Mr. Hellant, a very excellent obſerver, will give a parallax of the Sun much leſs than the other obſervations made in high Northern latitudes. In order to ſettle the longitude of this place, I am of opinion that we may have recourſe with ſafety, and without incurring the charge of reaſoning in a circle, to the obſervation of the tranſit itſelf; I mean the obſervation of the internal contact at the ingreſs. Whether we ſuppoſe the Sun's parallax to be $8''$ or $10''$, the firſt internal contact would have happened ſooner at Tornea° than at Stockholm $19''$ or $24''$. As the Sun's parallax will readilly be allowed to be more than $8''$, I ſhall ſuppoſe the firſt internal contact to have happened $21''$ ſooner. Tornea° is therefore $24'\ 55''$ to the Eaſt of Stockholm, and conſequently $1^h.37'.22''$ to the Eaſt of Greenwich. I ſhall make uſe of Mr. Hellant's obſervation of the internal contact at $21^h.54'.08''$ in preference to that of Mr. Lagerbom.

Abo, the capital of Finland, where Mr. Juſtander obſerved the laſt internal contact at $21^h.45'.19''$ (when a correction is made in the minutes) is $1^h.11'.29''$ to the Eaſt of Paris, and $1^h.28'.34''$ to the Eaſt of Greenwich.

At Hernoſand, which is $1^h.11'.29''$ to the Eaſt of Greenwich, I ſhall ſuppoſe the 2d internal contact was obſerved at $21^h.28'.52''$, as publiſhed in the Philoſophical Tranſactions by Mr. Short from the Swediſh acts.

I find the Iſland of Rodrigues by comparing three obſervations of eclipſes of Jupiter's ſatellites with

others made in England and at the Cape, to be $4^h.12'.38''$ to the East of Greenwich: and this determination is exactly confirmed by Mr. Pingré's comparison of the same eclipses. The observation of the occultation of a fixt star gives the longitude $6''$ or $7''$ greater. In the Philosophical Transactions, and even in the former part of the volume of the Memoirs of the Academy of Sciences for 1761, we find the internal contact was observed at Rodrigues at $0^h.34'.47''$; And yet in the memoire on the Sun's parallax it is said to have happened at $0^h.36'.49''$. Upon comparing this latter with the time by the clock, it should seem that Mr. Pingré had committed a mistake in subtracting the error of his clock instead of adding it. But he has no where mentioned any reason for this difference.

Gottingen, where the celebrated Mr. Mayer observed the first internal contact at $20^h.58'.26''$ to the East of Paris is $30'\ 16''$ or $39'\ 33''$ to the East of Greenwich.

The Abbé de la Caille has placed Bologna $36'.03''$ to the East of Paris: By comparing the observations of the transit of Mercury, I find, by a mean of three results agreeing very nearly together, that Bologna is $45'.15''$ to the East of Greenwich. Mr. Zanotti observed there the 2d internal contact at $21^h.04'.34''$. But as he used a refracting telescope of $2\frac{1}{2}$ feet, and as two other observers with telescopes of 10 and 22 feet saw the contact $24''$ later, I shall suppose it to have happened at $21^h\ 4'\ 58''$.

At Florence, the internal contact was observed with a reflector of more than 4 feet at $21^h.4'.28''$ by Father Ximenes. The longitude of this place is $34'\ 48''$ to the East of Paris, according to the table in the Connoissance des Mouvemens Celestes, or $35'.58''$ according

according to the table in the Elemens d'Aſtronomie by Mr. Caſſini. By taking a mean of both, Florence is 44'.40" to the Eaſt of Greenwich.

The longitude of St. Peters at Rome is 49'.54" according to the French Aſtronomers. The internal contact was obſerved to happen at $21^h.09'.36''$. But as it is not ſaid where this obſervation was made, the longitude given above will be found to be ſomewhat inaccurate.

Obſervations were alſo made at Madrid and Liſbon; at the former, the internal contact happened at $20^h.6'.56''$ apparent time: and at Liſbon at $19^h.44'.26''$. The longitude of Madrid, as given in the Philoſophical Tranſactions, is certainly erroneous; being more than a minute and a half too little, if the obſervation of the tranſit can be depended upon. At Liſbon, the longitude of the place was not determined by Mr. Ciera, who obſerved the tranſit, when Mr. Pingré, from whom I have taken the obſervation, left it in his way from Rodrigues. From the beſt accounts that I can collect, particularly from the 385th number of the Philoſophical Tranſactions, and from an account of ſome obſervations by Mr. Short, Liſbon is about 36'.26" to the Weſt of Greenwich.

Now in order to deduce the Sun's parallax from the obſervations related above, I proceeded in the following manner. Having ſubtracted the difference of longitude between Greenwich and the Cape $=1^h.13'.28''$ from $21^h.39'.52''$ the mean of the obſerved times at the Cape, and compared the remainder with the obſerved time at Greenwich, I find that the internal contact was obſerved 7'.24" later at the Cape

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than at Greenwich, on account of parallax. I then calculated what would be the effect of parallax at each place, suppoſing the Sun's parallax to be 9 ſeconds; and found that the time of the internal contact would be accelerated 1′.16″,63 at Greenwich, and retarded 6′.31′,09 at the Cape: the whole effect of parallax therefore is 7′.47″,72. But the difference in time, as found by obſervation, is only 7′.24″: and therefore the difference by calculation is to the difference by obſervation, as the aſſumed parallax is to the true parallax on the day of the tranſit, which by this obſervation is 8″,543. The parallax reſulting from each obſervation will be found in the following table, which will be ſufficiently explained by the foregoing example.

Places.	Difference of calculated times.	Difference of obſerved times.	Sun's parallax.
	′ ″	′ ″	″
Greenwich	7 47, 72	7 24	8, 543
Paris	7 28, 40	7 03, 5	8, 494
Stockholm	8 53, 72	8 41, 5	8, 712
Upſal	9 01, 83	8 45	8, 727
Cajaneburg	9 42, 30	9 32	8, 841
Tobolſki	10 29, 06	10 18, 5	8, 848
Tornea°	9 48, 95	9 38	8, 832
Abo	9 11, 16	8 59	8, 801
Hernoſand	9 21, 17	9 01	8, 676
Rodrigues	3 19, 72	2 13	5, 993
Gottingen	7 54, 36	7 31	8, 558
Bologna	7 03, 31	6 41	8, 525
Florence	6 57, 79	6 36	8, 536
Rome	6 45, 16	6 41	8, 907

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Such is the reſult of a compariſon of the beſt obſervations made in places whoſe longitudes are as accurately aſcertained as the preſent ſtate of Aſtronomy will permit: by a mean of the whole, rejecting only the obſervation at Rodrigues, the Sun's parallax on the day of the tranſit is 8″,692. — I have excluded the compariſon of the obſervation at Rodrigues, becauſe the parallax reſulting from it differs ſo conſiderably from the reſt. If we ſuppoſe the internal contact to have really happened one minute ſooner, through a miſtake in writing down the obſervation, the parallax will then be 8″,697.

This obſervation made at Rodrigues, ſuppoſing it exact, will furniſh another term wherewith to compare the ſeveral obſervations made in Europe. The Sun's parallax reſulting from each obſervation may be ſeen in the following table.

Places.	Difference of calculated times.	Difference of obſerv'd times.	Sun's parallax.	Difference of obſerved times.	Sun's parallax.
	′ ″	′ ″	″	′ ″	″
Greenwich - - - - -	4 28,00	5 11	10,444	4 11	8,429
Paris - - - - - -	4 8,98	4 50,5	10,500	3 50,5	8,332
Stockholm - - -	5 39,00	6 28,5	10,314	5 28,5	8,721
Upſal - - - - - -	5 42,11	6 32	10,312	5 32	8,734
Cajaneburg - - -	6 22,58	7 19	10,327	6 19	8,915
Tobolſki - - - - -	7 09,34	8 05,5	10,177	7 05,5	8,919
Tornea° - - - -	6 29,23	7 25	10,289	6 25	8,902
Abo - - - - - -	5 51,46	6 47	10,422	5 47	8,886
Hernoſand - - -	6 01,45	6 49	10,183	5 49	8,690
Gottingen - - -	4 34,64	5 18	10,421	4 18	8,454
Bologna - - - -	3 43,59	4 33	10,787	3 33	8,372
Florence - - - -	3 38,07	4 23	10,854	3 23	8,449
Cape of Good Hope -	3 19,72	2 13	5,993	3 13	8,697

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The mean of the whole, rejecting the comparison of the Cape, is $10'',419$; supposing the internal contact to have happened at $0^{h}.36'.49''$. But if a mistake of one minute was really committed, the 3d column will receive a considerable alteration and the parallax resulting from each observation will be represented in the last column, the mean of which is $8'',654$, agreeing as nearly as possible with the parallax resulting from all the best observations compared with the Cape.

Mr. Pingre finding the parallax resulting from his own observation to differ so widely from that deduced from the Cape, and that both observations might be made to agree by supposing an error of one minute in the observation at Rodrigues, has examined every source of error that might be committed; and upon the whole sees reason to prefer his own observation to that of Mr. Mason, *not because he could find no mistake in his own, but because he has proved that no mistake could possibly be committed.* His observation indeed is in some measure confirmed by comparing all the observations with that at Lisbon: from which comparison if the longitude above laid down may be depended upon, the Sun's parallax is somewhat more than 10 seconds.

The several observations, that have been compared with the observations both of the Cape and Rodrigues, may also be compared together; and by combining some of them, we may obtain different results, upon which we may more or less depend, as the differences between the observed times are greater or less.

Places

Places compared.	Difference of calculated times.		Difference of obferv'd times.		Sun's parallax.
	′	″	′	″	″
Tobolfki and Greenwich	2	41, 34	2	54, 5	9, 734
Tobolfki and Paris	3	0, 36	3	15	9, 736
Tobolfki and Gottingen	2	34, 70	2	47, 5	9, 744
Tobolfki and Stockholm	1	30, 34	1	37, 0	9, 663
Tobolfki and Upfal	1	27, 23	1	33, 5	9, 646
Tobolfki and Bologna	3	25, 75	3	37, 5	9, 513
Tobolfki and Florence	3	31, 27	3	42, 5	9, 525
Stockholm and Greenwich	1	11, [illegible]	1	17, 5	9, 824
Stockholm and Paris	1	30, 02	1	38, 0	9, 797
Stockholm and Bologna	1	55, 41	2	00, 5	9, 396
Stockholm and Florence	2	0, 93	2	05, 5	9, 340
Tornea° and Gottingen	1	54, 59	2	07	9, 974
Tornea° and Paris	2	20, 25	2	34, 5	9, 914
Tornea° and Greenwich	2	1, 23	2	14	9, 948
Cajaneburg and Greenwich	1	54, 58	2	08	10, 054
Cajaneburg and Paris	2	13, 60	2	28, 5	10, 003
Cajaneburg and Gottingen	1	47, 94	2	01	10, 088
Cajaneburg and Florence	2	44, 51	2	56	9, 628
Cajaneburg and Bologna	2	38, 99	2	51	9, 679
Upfal and Paris	1	33, 13	1	41, 5	9, 808
Upfal and Greenwich	1	14, 11	1	21	9, 836
Hernofand and Paris	1	52, 47	1	57, 5	9, 402
Hernofand and Greenwich	1	33, 45	1	37	9, 342
Hernofand and Bologna	2	17, 86	2	20	9, 139
Hernofand and Florence	2	23, 38	2	25	9, 101
Abo and Paris	1	42, 46	1	55, 5	10, 145
Abo and Greenwich	1	23, 44	1	33	10, 031
Abo and Bologna	2	07, 85	2	18	9, 714
Abo and Florence	2	13, 37	2	23	9, 649
Tornea° and Bologna	2	45, 64	2	57	9, 617
Tornea° and Florence	2	51, 16	3	02	9, 569
Greenwich and Paris	0	19, 02	0	20, 5	9, 700

The mean of the whole is 9″, 695.

	″
It has been ſhewn that the parallax reſulting from the total durations —— is	9, 579
— from a compariſon of the obſervation at Madraſs with thoſe of Tobolſki and Cajaneburg is — ——	9, 763
— from a compariſon of the obſerved, with a calculated, duration without parallax, is	9, 724
— from the leaſt diſtance of the centers —	9, 920
— from the obſervations combined together is	9, 695

It can hardly be ſuppoſed that as ſuch different methods give a parallax of the Sun on the day of the tranſit equal to 9″,736, that this parallax ſhould yet be only 8,692 as deduced from a compariſon of the obſervations with the Cape, while the ſame obſervations compared with thoſe of Rodrigues and Liſbon ſhew that the parallax exceeds 10 ſeconds. Let us therefore ſuppoſe that the obſervers at the Cape have ſet down their obſervation one minute too ſoon, tho' it muſt be confeſſed that the time of the duration at the egreſs cannot warrant ſuch a correction, and that the time of the internal contact ſhould have been obſerved at $21^{h}.40'.52''$; the parallax, by taking a mean, will then be 9″,732, exactly agreeing with a mean of all the other determinations. And in this Quantity of the Sun's parallax we muſt either acquieſce, or remain as ignorant of the true quantity of it as we we were before, till we can have recourſe to the next tranſit on June 3d 1769, when the planet Venus will again paſs over the Sun's diſk, having ſomething

more

more than 10 minutes of North latitude; and will be ſo favourably circumſtanced, that, if the errors in obſerving each contact do not exceed 4″ or 5″, the quantity of the Sun's parallax may be determined within leſs than $\frac{1}{100}$th part of the whole: as the total duration, or the interval between the two internal contacts, will be found to be about 18 minutes longer at Tornea° than at Mexico. But the ſeveral circumſtances of that tranſit muſt be the ſubject of a future paper. Let it ſuffice at preſent to obſerve that it will in part be viſible to the inhabitants of this iſland, as Venus will be ſeen wholly entered upon the Sun's diſk more than half an hour before the time of ſun-ſet at Greenwich.